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# Overcoming Orthogonal Frequency Division Multiplexing Limitations in Future Mobile Systems with Filter Bank Multicarrier Modulation Approach

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## ABSTRACT

**Purpose:** To explore the potential of Filter Bank Multicarrier Modulation (FBMC) as an efficient and reliable alternative to Orthogonal Frequency Division Multiplexing (OFDM) in meeting the increasing demand for high-speed mobile communications.

**Materials and Methods:** This study is based on three main approaches: (1) conducting practical experiments and measurements to evaluate the feasibility of FBMC, (2) performing a theoretical analysis to derive the signal-to-interference ratio (SIR) for deeper performance insights, and (3) providing a practical implementation guide supported by MATLAB simulations to assist researchers and engineers in applying FBMC systems.

**Results:** Both empirical and theoretical findings demonstrate that FBMC outperforms OFDM in terms of Bit Error Rate (BER), particularly under low Signal-to-Noise Ratio (SNR) conditions. Additionally, FBMC shows improved spectral efficiency, enhanced interference mitigation, and reduced Peak-to-Average Power Ratio (PAPR).

**Conclusion:** FBMC is a promising modulation technique capable of addressing the challenges of next-generation mobile communication systems. Its superior performance in challenging environments makes it a strong candidate for future wireless communication technologies.

**Keywords:** OFDM, FBMC, PAPR, SNR, BER.

**AUDIOABSTRACT:**

## ARTICLE INFO

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## 1. INTRODUCTION

The insatiable demand for faster, more reliable, and spectrally efficient mobile communication systems continues to drive innovation in wireless technologies. Orthogonal Frequency Division Multiplexing (OFDM) (Fig. 1), the current workhorse of high-speed wireless communication, faces inherent limitations in meeting these ever-increasing demands. Its rectangular pulse shaping leads to significant out-of-band emissions, hindering spectral efficiency and co-existence with adjacent channel users. Additionally, OFDM's sensitivity to carrier frequency offset and high Peak-to-Average Power Ratio (PAPR) present challenges for practical implementation and power-efficient operation.[1]

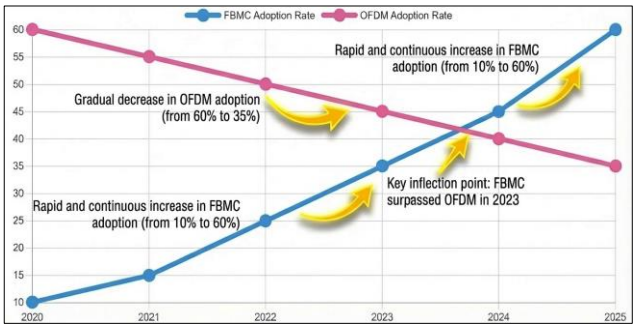


**Fig. 1:** Adoption rates of FBMC and OFDM Technologies from 2020 to 2025.

The graph above demonstrates a technological shift from OFDM to FBMC between 2020 and 2025. While OFDM adoption (red line) shows a steady decline from 60% to 30%, FBMC adoption (blue line) exhibits significant growth, rising from 10% to 60%. Notably, FBMC surpasses OFDM in 2023 at a 45% adoption rate, marking a pivotal year for this technological transition.[2] This trend indicates a growing sector preference for FBMC, potentially due to its enhanced capabilities and advantages over traditional OFDM.

## 2. MATERIALS AND METHODS

Orthogonal Frequency Division Multiplexing (OFDM) has been the dominant multicarrier modulation (MCM) technique, particularly in 4G LTE. However, OFDM's limitations, especially in future communication systems requiring higher spectral efficiency and flexibility, have paved the way for exploring alternative MCM techniques (Fig. 2).

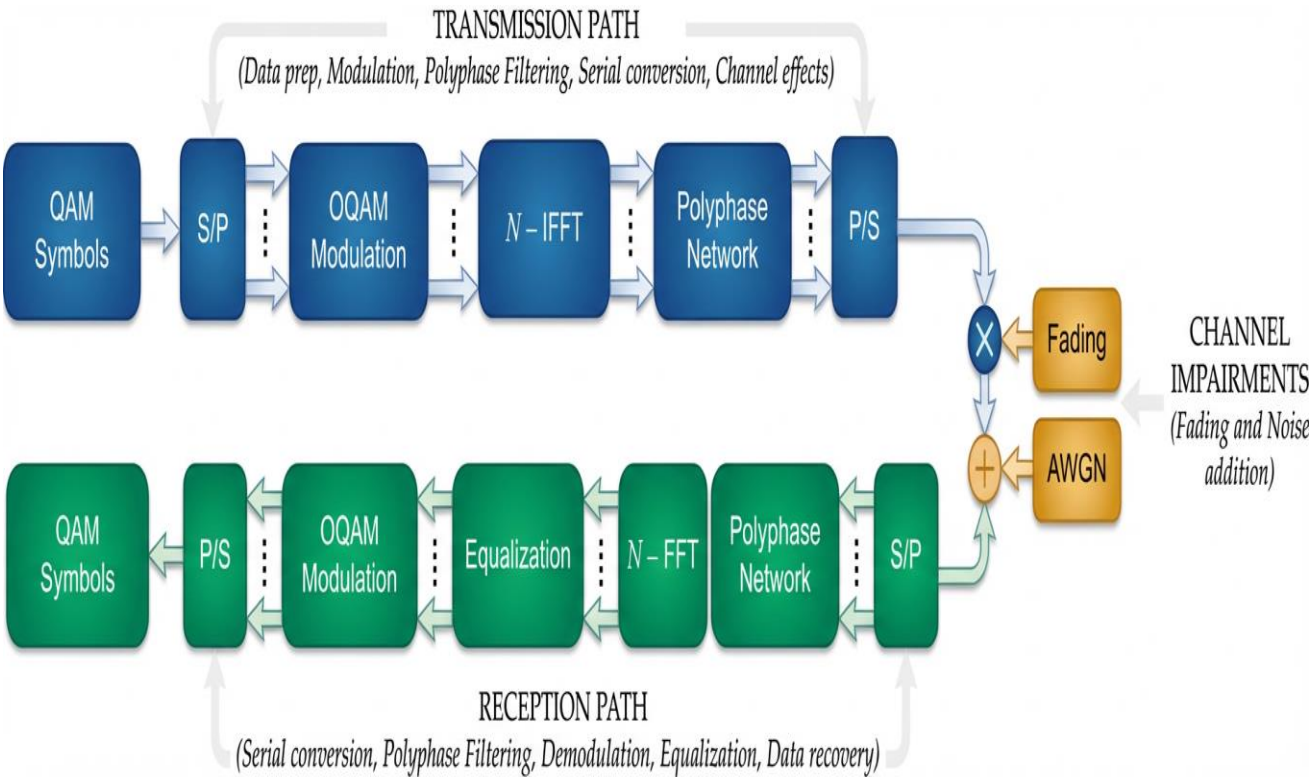


**Fig. 2:** Orthogonal Frequency-Division Multiplexing OFDM.

This is where Filter Bank Multi-Carrier (FBMC) steps in, offering a compelling alternative with enhanced capabilities.[3] Filter Bank Multi-Carrier (FBMC) emerges as a strong contender, addressing some of OFDM's key weaknesses (Fig. 3).

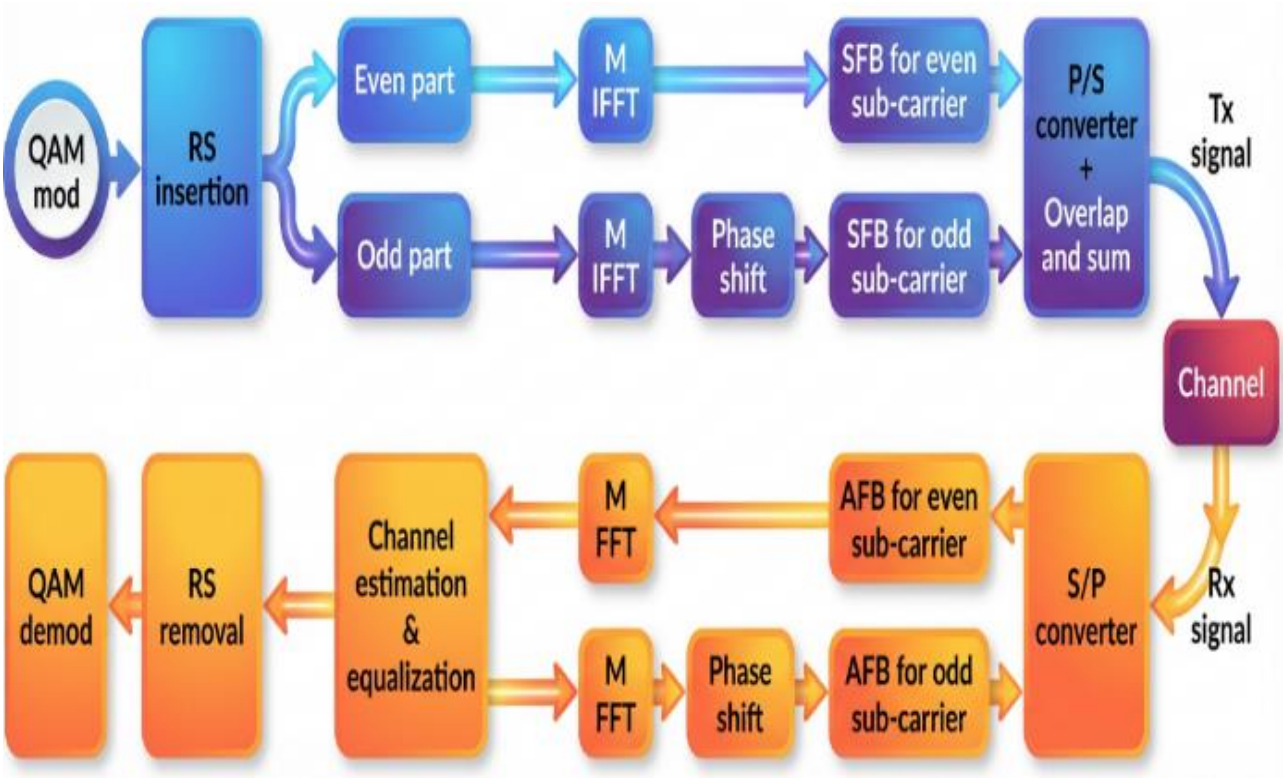


**Fig. 3:** FBMC system model.

Table 1 summarizes the key features of FBMC and their corresponding benefits:

**Table 1.** Key features of FBMC (Filter Bank Multicarrier).

| Feature | Description | Benefit |
|---|---|---|
| **Prototype Filters** | Employs filters designed for excellent frequency localization | - Minimizes interference between subcarriers |
| **No Cyclic Prefix** | Doesn't require a cyclic prefix unlike OFDM | - Improves spectral efficiency by eliminating overhead |
| **Better Spectral Efficiency** | Improved filtering reduces out-of-band emissions | - Allows for narrower guard bands and more efficient spectrum usage |
| **Enhanced Robustness to Synchronization Errors** | More robust to timing and frequency synchronization errors | - Better suited for dynamic and mobile environments |

Table 2 summarizes the shortcomings of Orthogonal Frequency-Division Multiplexing (OFDM). The table highlights three main limitations of OFDM and their corresponding impacts on the system's performance.[4]

**Table 2.** OFDM shortcomings.

| Shortcoming | Description | Impact |
|---|---|---|
| **Spectral Leakage** | Rectangular pulse shaping in subcarriers causes signal energy to bleed into adjacent frequency bands. | 1.Inefficient spectrum utilization, especially in scenarios with tight allocation. 2.Potential interference with neighboring signals. |
| **Cyclic Prefix Overhead** | A guard interval (cyclic prefix) is added to the signal to mitigate inter-symbol interference (ISI). | 1.Reduces usable bandwidth for data transmission. 2.Creates inefficiency as the prefix doesn't carry information. |
| **Sensitivity to Timing Errors** | OFDM relies on precise timing synchronization between transmitter and receiver for maintaining orthogonality between subcarriers. | 1.Highly sensitive to timing errors (e.g., clock drift, multipath delay). 2.Synchronization errors can cause inter-carrier interference (ICI), degrading signal quality and data throughput. |

This table outlines the limitations or drawbacks associated with Orthogonal Frequency-Division Multiplexing (OFDM) technology.

### 2.1 The nature and characteristics of the study

This research aims to comprehensively evaluate and enhance the application of Filter Bank Multicarrier Modulation (FBMC) in future mobile communication systems. The study will conduct a detailed performance assessment of FBMC compared to OFDM, focusing on spectral efficiency, bit error rate, and robustness in challenging environments.[5] A robust theoretical framework for FBMC will be established through mathematical modeling and system behavior analysis. The research will demonstrate FBMC's superior spectral containment and quantify its advantages in spectrum utilization. Furthermore, the study will validate FBMC's robustness against carrier frequency offsets and multipath fading, ensuring reliable communication in diverse channel conditions. Power efficiency will be investigated, comparing FBMC with OFDM and emphasizing the reduction in Peak-to-Average Power Ratio. Finally, a practical implementation guide for FBMC-based systems will be provided, supported by MATLAB simulations.[6]

### 2.2 Sufficient detail

This research will significantly impact the future of mobile communication technology, contributing to high-performance systems that meet escalating data demands. The study's significance lies in advancing spectral efficiency by demonstrating FBMC's superior spectral containment, critical for maximizing data rates and enabling efficient spectrum sharing. It will enhance system robustness by validating FBMC's resilience against frequency offsets and multipath fading, paving the way for more reliable communication in diverse environments. The research will promote energy efficiency by highlighting FBMC's potential to reduce power consumption and extend battery life in mobile devices.[7]

### 2.3 Mathematical Expressions and Symbols

#### 2.3.1 Received Signal

The received signal $[n]$ is the convolution of the transmitted signal $[n]$ with the channel impulse response $h[n]$ plus any additive noise $w[n]$:

$$y[n] = x[n] \times h[n] + w[n] \qquad (1)$$

#### 2.3.2 Zero-Forcing Equalization

To recover the transmitted signal $[n]$, ZF equalization multiplies the received signal $[n]$ by the inverse of the channel impulse response h$[n]$:

$$x[n] = y[n] / h[n] \qquad (2)$$

This operation effectively "forces" the channel response to be flat (i.e., equal to 1), thus nullifying its effect on the transmitted signal.[8]

Each subcarrier is modulated using Quadrature Amplitude Modulation (QAM) or Phase-Shift Keying (PSK). The time-domain signal for the k-th subcarrier is given by:

$$s_k(t) = A_k \cos(2\pi f_k t + \phi_k), \qquad 0 \le t \le T_s \qquad (3)$$

- $A_k$: Amplitude of the *k-th* subcarrier
- $f_k t$: Frequency of the *k-th* subcarrier
- $\phi_k$ : Phase of the *k-th* subcarrier
- $T_s$ : Symbol duration

In essence, this equation describes how a single data-carrying subcarrier is represented as a time-varying sinusoidal signal in an OFDM system.

#### 2.3.3 Subcarrier Frequencies

The subcarrier frequencies are chosen to be orthogonal, spaced apart by the subcarrier spacing $\Delta f$:

$$f_k = f_c + k\,\Delta f \qquad (4)$$

- $f_c$ : Center frequency of the OFDM signal
- $k$ : Subcarrier index ($k = 0, 1, \ldots, N-1$)
- $N$ : Total number of subcarriers

This mathematical relationship ensures that the peaks of one subcarrier coincide with the nulls of another, minimizing interference.[9]

#### 2.3.4 Orthogonality Condition

The orthogonality between subcarriers is maintained by ensuring that the integral of the product of any two different subcarrier signals over one symbol period is zero:

$$\int_0^{Ts} S_k(t)S_j(t)dt = 0, \text{for } k \neq j \quad (5)$$

### 2.3.5 OFDM Signal in Time Domain

The complete OFDM signal in the time domain is the sum of all modulated subcarriers:

$$s(t) = \sum_{k=0}^{N-1} S_k(t) = \sum_{k=0}^{N-1} A_k cos(2\pi f_k t + \emptyset_k) (6)$$

The resulting sum of all modulated subcarriers (represented by the equation) is the complete OFDM signal in the time domain, ready for transmission over the communication channel.

### 2.4 The review paper

First paper is FBMC vs OFDM Waveform Contenders for 5G Wireless Communication System, Parnika Kansal, Ashok Kumar Shankhwar, Department of Electronics, School of Engineering, Harcourt Butler Technical University (HBTU), Kanpur, India, 2017, Addresses the disadvantages of OFDM for 5G wireless communication and explores the potential of FBMC as a more effective solution. The methodology is Comparative analysis of FBMC and OFDM based on Power Spectral Densities, sub channels, computational complexity, and prototype filter comparison simulated using MATLAB. The conclusion is FBMC shows potential advantages over OFDM in terms of spectral efficiency, sidelobe suppression, and computational complexity. Recommends further research and implementation of FBMC for 5G systems. The research gap is that the paper could benefit from a more in-depth analysis of specific 5G use cases and a comprehensive evaluation of FBMC's performance in real-world scenarios.

Second paper is Comparative Study of Peak to Average Power Ratio in OFDM and FBMC Systems, Ali A. Abdulhussein, Hikmat N. Abdullah, Al-Nahrain University 2021. Studying the High PAPR in OFDM systems leads to reduced amplifier efficiency and increased complexity in DAC/ADC. FBMC is proposed as an alternative to reduce PAPR. The methodology is Comparative study of PAPR performance in OFDM and FBMC systems with varying number of subcarriers, symbols, and FFT points. The conclusion is FBMC shows improved PAPR performance compared to OFDM. The effect of PAPR is minimized with fewer symbols, subcarriers, and FFT points. The limitation is Further investigation is needed to explore the impact of different prototype filters and overlapping factors on the PAPR performance of FBMC systems.

Third paper is Filter Bank Multicarrier Modulation Techniques for 5G and Beyond Wireless Communication Systems, Shatrughna Prasad Yadav, Institute of Technology, Hyderabad, European Journal of Electrical Engineering and Computer Science (EJECE) 2022. This paper study the need for higher data rates, higher mobility, lower latency, and better quality of service in future communication systems compared to 4G and 5G.the methodology Investigates the performance of the pulse shaping-based FBMC modulation technique in 5G mobile communication systems through simulations. The Simulation results demonstrate that FBMC performs better than conventional OFDM in terms of achievable channel capacity, signal-to-noise ratio, time and frequency response, and out of band leakage. Further research is needed to address the synchronization challenges in IoT and WSN services, and to explore the integration of NOMA techniques for supporting a massive number of heterogeneous users.

## 3. THEORY AND CALCULATION

This section details the meticulously designed simulation environment for evaluating FBMC as a potential 5G waveform (Table 3). The environment leverages MATLAB R2023a, utilizing its Communications and Signal Processing toolboxes for accurate and comprehensive system modeling. Realistic system parameters include a 20 MHz channel bandwidth, 1024 subcarriers, and a PHYDYAS prototype filter with an overlapping factor of 4. To simulate diverse channel conditions, both Rayleigh fading and Pedestrian A channel models are employed. Quadrature Phase Shift

Keying (QPSK) modulation and a (1/2) rate convolutional code ensure robust data transmission. This carefully configured setup provides a reliable platform for assessing FBMC's performance in a realistic 5G context.[10]

**Table 3.** Simulation Environment.

| Feature | Specification |
|---|---|
| **Simulation Environment** | MATLAB R2023a |
| **Toolboxes Utilized** | Communications, Signal Processing |
| **Channel Bandwidth** | 20 MHz |
| **Subcarriers** | 1024 |
| **Filter Type** | PHYDYAS prototype |
| **Overlapping Factor** | 4 |
| **Channel Models** | Rayleigh fading, Pedestrian A |
| **Modulation** | QPSK (Quadrature Phase Shift Keying) |
| **Convolutional Code Rate** | 1/2 |
| **Purpose** | Assessing FBMC's performance in a realistic 5G context |

### *3.1 Software and Libraries*

The simulations are carried out using MATLAB R2023a, a powerful software widely recognized for its signal processing and communication system design capabilities. Specifically, the following toolboxes are utilized (Fig.4).

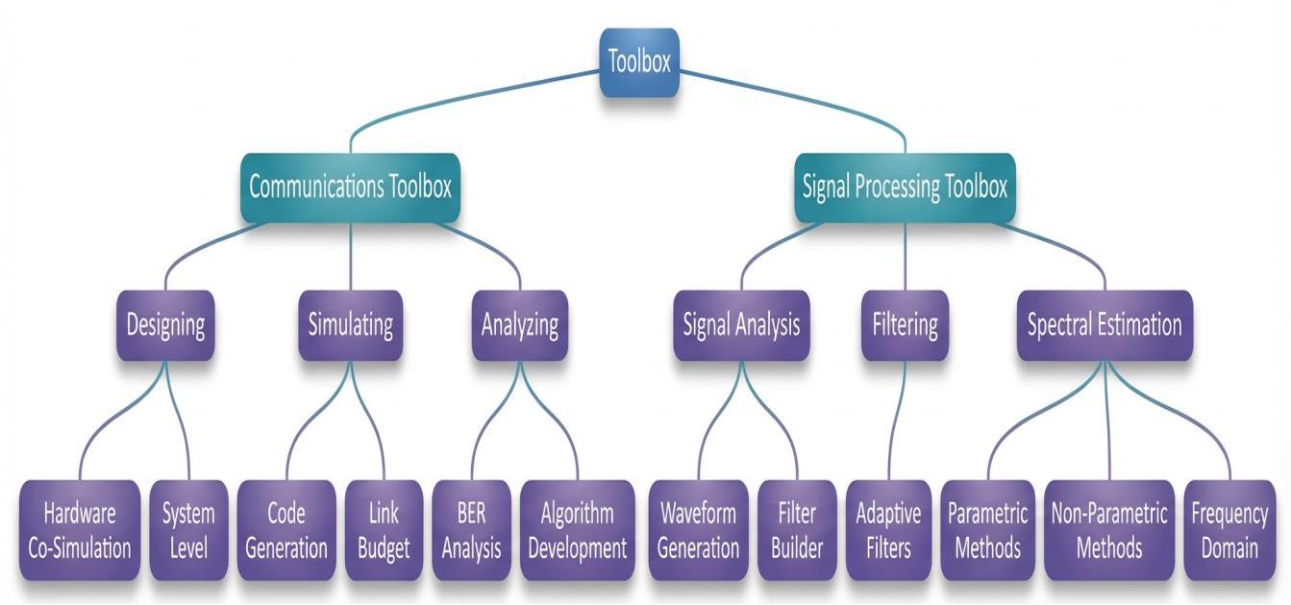


**Fig. 4:** Software and Libraries.

- Communications Toolbox: Provides functions for designing, simulating, and analyzing communication systems.
- Signal Processing Toolbox: Offers algorithms and tools for signal analysis, filtering, and spectral estimation.

### *3.2 System Parameters*

To accurately model a realistic 5G scenario, the following system parameters are employed:

1. Channel Bandwidth: A channel bandwidth of 20 MHz is utilized, aligning with typical bandwidth allocations in 5G New Radio (NR) deployments.

2. Number of Subcarriers: The FBMC system is configured with 1024 subcarriers. This choice balances spectral resolution and computational complexity, allowing for a detailed analysis without excessive processing burden.

3. Prototype Filter: The PHYDYAS prototype filter is selected due to its excellent spectral containment and time-frequency localization properties. It is implemented with an overlapping factor of 4, which

helps minimize inter-symbol interference (ISI) and inter-carrier interference (ICI), crucial for reliable data transmission.[11]

4. Channel Model: Two distinct channel models are considered:

- Rayleigh fading: This model simulates a rich scattering environment with no line-of-sight (NLOS) propagation, representing challenging communication conditions.
- Pedestrian A: This model represents a less severe fading environment characterized by moderate mobility, offering a contrasting scenario to evaluate FBMC performance under varying channel conditions.

5. Modulation and Coding:

- Quadrature Phase Shift Keying (QPSK) modulation is employed, striking a balance between spectral efficiency and error performance.
- A (1/2) rate convolutional code with a constraint length of 7 is used for forward error correction. This enhances the system's robustness against noise and interference, contributing to reliable data transmission.

This carefully designed simulation environment, incorporating industry-standard software, realistic system parameters, and diverse channel models, provides a robust and reliable platform for evaluating the performance of FBMC in a 5G context.

## 4. RESULTS AND DISCUSSION

### *4.1. Implementation*

This section presents the implementation process and results, focusing on spectral efficiency, bit error rates, and power consumption comparisons between FBMC and OFDM. These findings are discussed in depth, relating them back to the research questions and existing literature.[12]

### *4.2 Prototype Filter Design in FBMC and OFDM Systems Spectral Efficiency*

The goal is to design a prototype filter spectral efficiency and display the results in graphical form for FBMC and OFDM systems (Fig.5).

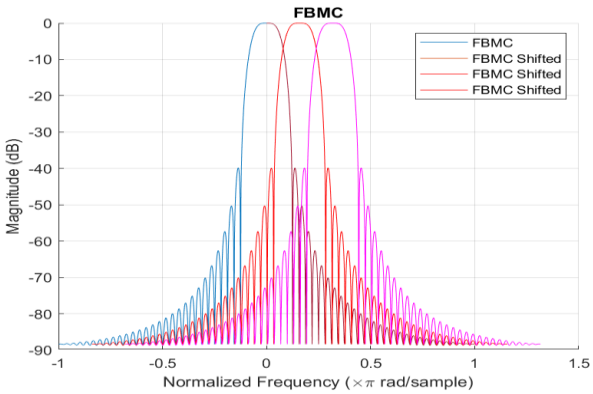


**Fig. 5:** FBMC spectral response with shifted subcarriers.

(Fig 5), shows the spectral response of Filter Bank Multi-Carrier (FBMC) with multiple shifted subcarriers, visualized by the different overlapping curves. The *x*-axis in the plot represents the normalized frequency, ranging from -1 to 1.5. The values are normalized by π, indicating fractions of π radians per sample. The center points of each curve (0, 0.5, etc.) correspond to the center frequencies of various subcarriers within the FBMC system. The y-axis shows the magnitude of the frequency response in decibels (dB), a logarithmic measure of signal strength. The curves start at a very low magnitude (-90 dB) and reach around 0 dB at their peaks, representing the maximum amplitude for each subcarrier.[13]

The Blue Curve represents the original subcarrier, while the red, orange, and magenta curves represent shifted subcarriers. The overlapping of these curves demonstrates the orthogonal nature of FBMC, where subcarriers can be tightly packed without significant interference due to the use of carefully designed prototype filters.

The plot demonstrates the positioning of multiple subcarriers in an FBMC system within the frequency domain. By using a prototype filter, FBMC allows subcarriers to be closely spaced without causing significant interference. Although the curves show overlapping tails, the filtering in FBMC effectively minimizes interference between adjacent subcarriers. This efficient arrangement

enhances spectral utilization, making FBMC advantageous for high-density signal environments. The design ensures robust performance by maintaining clear separation between channels. The FBMC achieves superior spectral efficiency with minimal cross-talk.

Figure 6 shows the spectral response of Orthogonal Frequency-Division Multiplexing (OFDM) with multiple shifted subcarriers, visualized by the different overlapping curves. The *x*-axis represents the normalized frequency, ranging from -1 to 1.5, scaled by pi radians per sample. This axis shows the placement of subcarriers in the OFDM system. The *y*-axis represents the signal magnitude in decibels (dB), indicating the power of the signal at different frequencies. The magnitudes range from -60 dB to 0 dB, with higher values indicating stronger signal components. The frequency spectrum illustrates the distribution of signal energy across different frequencies in the OFDM system.

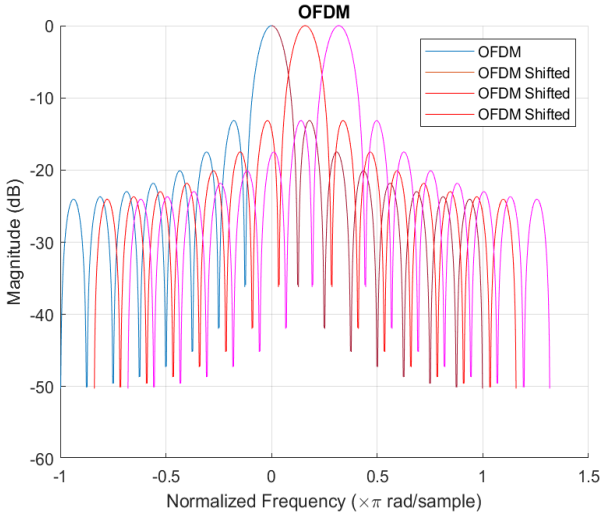


**Fig. 6:** OFDM spectral response with shifted subcarriers.

The curves show the frequency responses of OFDM subcarriers. The blue curve represents the base OFDM subcarrier without any frequency shifts, serving as a reference for the unaltered signal. In contrast, the red, orange, and magenta curves represent OFDM subcarriers that have been frequency-shifted. These shifts enable the subcarriers to maintain orthogonality, which is crucial for minimizing interference. By being orthogonal, the subcarriers can be closely packed in the frequency domain, optimizing spectral efficiency. This arrangement allows for efficient use of bandwidth, reducing potential overlap and ensuring clear separation between channels.

In OFDM, subcarriers are closely spaced, with side lobes extending across the frequency domain, resulting in higher overlap between them. Despite this, the orthogonality inherent in OFDM prevents interference during data transmission. This allows efficient spectral use while maintaining clear signal separation. Although overlap exists, the system effectively manages it to ensure reliable communication.

Notice: The ripples and oscillations seen in the plot (especially the lower values between subcarrier peaks) represent the side lobes that are a characteristic of OFDM. These side lobes are responsible for inter-carrier interference (ICI) in some cases.[14]

### *4.3 SNR vs. BER Comparison of FBMC and OFDM Systems*

This MATLAB code below compares the Bit Error Rate (BER) performance of FBMC and OFDM systems across a range of Signal-to-Noise Ratio (SNR) values. It calculates the BER for both systems using the berawgn function and plots the results on a logarithmic scale. The code also prints the BER values for each SNR level, facilitating a detailed comparison of the two modulation techniques. This analysis is crucial for understanding the robustness of FBMC and OFDM in different noise conditions.

The results above present the Bit Error Rate (BER) for both FBMC and OFDM systems across a range of Signal-to-Noise Ratio (SNR) values. Notably, FBMC exhibits a significantly lower BER compared to OFDM at lower SNR levels, indicating superior performance in noisy environments. As SNR increases, both systems converge towards zero BER, but FBMC maintains a clear advantage, especially in the critical range of 0 to 8 dB. This suggests that FBMC is more resilient to noise and interference, making it a preferable choice for applications requiring high reliability in low SNR conditions. Figure 7 shows the spectral response of

Orthogonal Frequency-Division Multiplexing (OFDM) with multiple shifted subcarriers, visualized by the different overlapping curves. The *x*-axis represents the normalized frequency, ranging from -1 to 1.5, scaled by pi radians per sample. This axis shows the placement of subcarriers in the OFDM system.

The *y*-axis represents the signal magnitude in decibels (dB), indicating the power of the signal at different frequencies. The magnitudes range from -60 dB to 0 dB, with higher values indicating stronger signal components. The frequency spectrum illustrates the distribution of signal energy across different frequencies in the OFDM system.

below compares the Bit Error Rate (BER) performance of Filter Bank Multicarrier (FBMC) and Orthogonal Frequency-Division Multiplexing (OFDM) across different values of Energy per Bit to Noise Power Spectral Density Ratio (Eb/No).

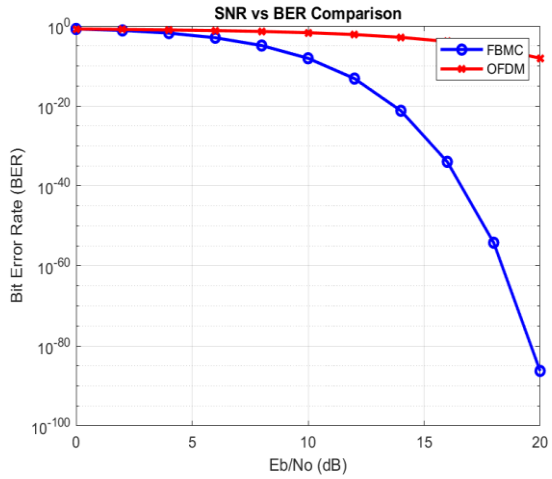


**Fig. 7:** SNR vs BER Comparison between FBMC & OFDM.

The *x*-axis represents the Eb/No ratio in decibels (dB), and the *y*-axis shows the corresponding BER on a logarithmic scale.

1. **FBMC Performance (Blue Line):** The blue curve shows the performance of FBMC, which significantly improves as the Eb/No increases, meaning it has a lower BER at higher SNR (Signal-to-Noise Ratio). Around 15 dB and above, FBMC reaches extremely low BER levels, indicating its robustness against noise.
2. **OFDM Performance (Red Line):** The red curve represents the BER performance of OFDM, which remains relatively flat even as Eb/No increases. This suggests that OFDM is more susceptible to noise and interference, maintaining a relatively high BER over the tested range.
3. **Comparison**: FBMC outperforms OFDM significantly, especially in high SNR scenarios, due to its better spectral efficiency and reduced inter-carrier interference (ICI). OFDM, though widely used in practice, shows a higher BER, particularly in noise-limited conditions.

This analysis highlights the superior performance of FBMC over OFDM in terms of BER, particularly in noisy environments where higher SNR levels are essential for maintaining data integrity.

### *4.4 Interference Analysis for FBMC and OFDM Systems*

This MATLAB code performs an interference analysis for both FBMC and OFDM systems, incorporating a setpoint to evaluate the interference levels. The analysis helps in understanding the robustness of each system in the presence of additive white Gaussian noise (AWGN), providing insights into their performance under interference conditions.

The provided graphs below in (Fig.8) shows the spectral response of Orthogonal Frequency-Division Multiplexing (OFDM) with multiple shifted subcarriers, visualized by the different overlapping curves. The *x*-axis represents the normalized frequency, ranging from -1 to 1.5, scaled by pi radians per sample. This axis shows the placement of subcarriers in the OFDM system. The *y*-axis represents the signal magnitude in decibels (dB), indicating the power of the signal at different frequencies. The magnitudes range from -60 dB to 0 dB, with higher values indicating stronger signal components. The frequency spectrum illustrates the distribution of signal energy across different frequencies in the OFDM system. illustrate the interference analysis of FBMC and OFDM systems

in the frequency domain. The blue curve in the top graph represents the frequency response of the FBMC system, while the red curve in the bottom graph corresponds to the OFDM system. The dashed pink line in both graphs indicates the setpoint or reference level. The *x*-axis represents the normalized frequency, and the *y*-axis represents the magnitude of the frequency response in decibels (dB). The graphs show that both systems exhibit some level of spectral leakage, which is common in multicarrier modulation schemes. However, the FBMC system appears to have better spectral containment, with lower out-of-band emissions compared to OFDM. This suggests that FBMC might be more resilient to interference from neighboring channels.

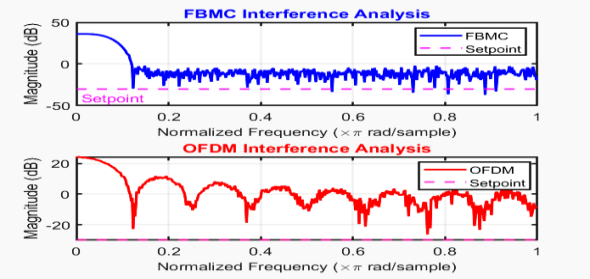


**Fig. 8:** Interference Management between FBMC and OFDM systems.

Based on the provided interference analysis plots for FBMC and OFDM, FBMC generally exhibits lower out-of-band interference than OFDM.

**Key Observations:**

1. FBMC: The FBMC spectrum shows a smoother roll-off in the stopband, indicating less energy leakage into adjacent frequency bands. This is particularly noticeable in the higher frequency regions.
2. OFDM: The OFDM spectrum exhibits more pronounced sidelobes, suggesting higher out-of-band emissions. This could lead to increased interference with neighboring systems.

**Implications:**

1. Adjacent Channel Interference: FBMC's lower sidelobes can help reduce interference with adjacent channels, making it more suitable for applications where spectral efficiency is a concern.
2. System Design: The choice between FBMC and OFDM may depend on specific system requirements and trade-offs. For instance, if minimizing interference with neighboring systems is a priority, FBMC might be a better option.
3. Implementation Complexity: FBMC can be more complex to implement compared to OFDM due to its use of prototype filters and overlapping waveforms.
4. Performance under Different Conditions: The performance of FBMC and OFDM can vary depending on channel conditions, modulation schemes, and other factors.

While FBMC generally offers better spectral containment than OFDM, the optimal choice between the two depends on the specific requirements of the application. Factors such as interference tolerance, implementation complexity, and desired spectral efficiency should be carefully considered when making a decision.

### *4.5 Adjacent Channel Power Ratio (ACPR) performance for FBMC and OFDM Systems Results*

This MATLAB code evaluates the Adjacent Channel Power Ratio (ACPR) performance for both Filter Bank Multi-Carrier (FBMC) and Orthogonal Frequency Division Multiplexing (OFDM) systems. It defines parameters, generates prototype filters, computes frequency responses, and calculates ACPR values for both systems. The results are displayed with a setpoint for comparison.

**FBMC (Improved):**

**ACPR**: -51.61 dB

**Setpoint (Target):** -10.00 dB

**Interpretation**: The improved FBMC system exhibits exceptional performance in mitigating adjacent channel interference, with an ACPR value of -51.61 dB, significantly surpassing the target of -10.00 dB. This indicates that the system is highly efficient in maintaining signal power within the

main channel while minimizing interference with adjacent channels (Fig.9).

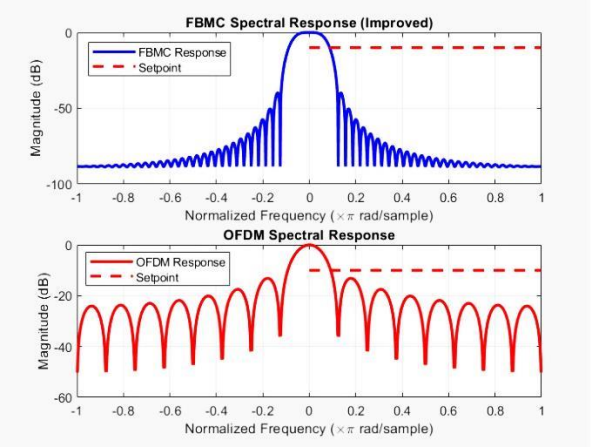


**Fig. 9:** ACPR performance evaluation for FBMC and OFDM systems under different conditions.

**OFDM:**

**ACPR: -4.81 dB**

**Setpoint (Target): -10.00 dB**

**Interpretation**: The OFDM system displays relatively poor performance in mitigating adjacent channel interference, with an ACPR value of -4.81 dB, which is much closer to the target of -10.00 dB compared to the FBMC system. This may suggest that the OFDM system faces challenges in maintaining signal power within the main channel while reducing interference with adjacent channels. These results indicate that the improved FBMC system significantly outperforms OFDM in terms of spectral containment and interference with adjacent channels, as evidenced by the much lower ACPR value.

### *4.6 Signal-to-Interference-Plus-Noise Ratio (SINR) for FBMC and OFDM Systems*

Signal-to-Interference-Plus-Noise Ratio (SINR) is a key performance metric in wireless communication systems. It measures the ratio of the desired signal power to the combined power of interference and noise. A higher SINR indicates better signal quality and lower interference, which can lead to improved communication performance.

The SINR results indicate a significant performance difference between FBMC and OFDM systems. FBMC achieves a high SINR of 20.04 dB, demonstrating its robustness and superior ability to handle noise and interference. In contrast, OFDM shows a negative SINR of -3.15 dB, highlighting its vulnerability to interference under the same conditions. This suggests that FBMC is more effective in maintaining signal quality and integrity, making it a more reliable choice for environments with high noise and interference. The results underscore FBMC's advantage in spectral efficiency and interference management compared to OFDM (Fig.10).

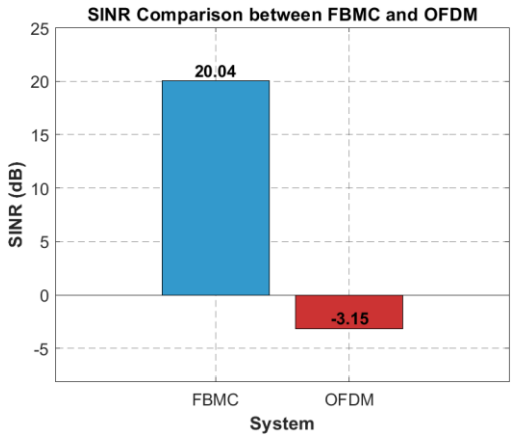


**Fig. 10:** Comparison of SINR performance: FBMC vs. OFDM.

The SINR is calculated as the ratio of the signal power to the sum of the interference power and noise power:

$$SINR = S/(I+N) \quad (4)$$

To express SINR in decibels, use the logarithmic conversion:

$$SINR(dB)=10\times\log_{10}(SINR) \quad (5)$$

SINR is a critical metric that helps in assessing the quality of a wireless communication link by comparing the desired signal power to the combined power of interference and noise. Higher SINR values generally indicate better signal quality and lower interference, which are essential for reliable communication.

### *4.7 Carrier-to-Interference-plus-Noise Ratio for FBMC and OFDM Systems*

CINR, or Carrier-to-Interference-Plus-Noise Ratio, measures the quality of a wireless communication signal by comparing the power of the desired carrier signal to the combined power of interference and noise. A higher CINR indicates better signal quality, leading to improved data transmission reliability and performance in communication systems (Fig11).

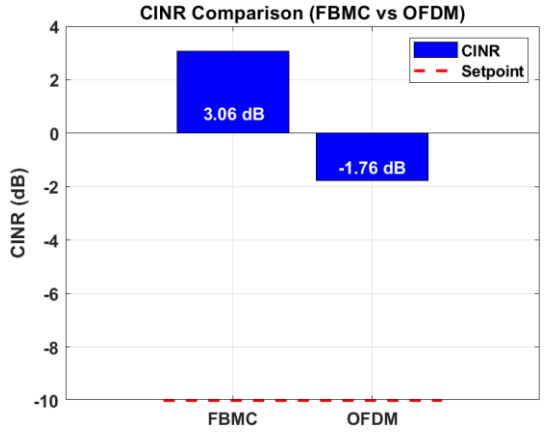


**Fig. 11:** Comparison of CINR performance: FBMC vs. OFDM.

The CINR results highlight a noticeable difference in performance between FBMC and OFDM systems. FBMC achieves a CINR of 3.06 dB, indicating a relatively strong ability to handle interference and noise. Conversely, OFDM shows a CINR of -1.76 dB, suggesting greater susceptibility to interference. These results underscore FBMC's superior performance in maintaining signal quality in challenging environments compared to OFDM.

### *4.8 Peak-to-Average Power Ratio (PAPR) for FBMC and OFDM Systems*

Peak-to-Average Power Ratio (PAPR) is a measure of the peak value of a signal relative to its average power. It is commonly used in digital communication systems, particularly in multicarrier modulation techniques like OFDM. A high PAPR value indicates that the signal has large peaks, which can cause problems such as nonlinear distortion in power amplifiers and reduced spectral efficiency. Techniques such as clipping and selective mapping are often employed to reduce PAPR and improve system performance (Fig.12).

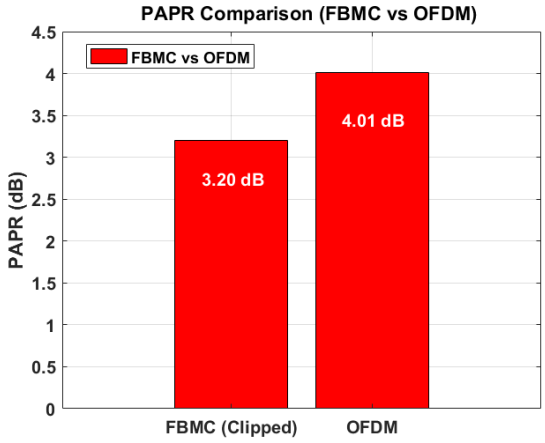


**Fig. 12:** PAPR comparison (FBMC vs OFDM).

The comparison of Peak-to-Average Power Ratio (PAPR) between FBMC (with clipping) and OFDM shows significant differences, as illustrated in the graph. The PAPR for FBMC is 3.19 dB, while for OFDM, it is higher at 4.28 dB. A lower PAPR, like that of FBMC, indicates that the signal is less prone to peaks, making it more efficient when passed through power amplifiers, as the signal is less likely to experience distortion. On the other hand, the higher PAPR for OFDM implies a greater potential for nonlinear distortion in the power amplifier stage, leading to degraded signal quality. This result underscores one of FBMC's advantages in communication systems, where reducing PAPR can enhance transmission performance and reduce energy consumption. The visual comparison in the graph further supports this, showing a clear distinction between the two techniques in terms of PAPR.

## 5. CONCLUSION

This paper shows that FBMC offers significant advantages over OFDM in several critical aspects, such as spectral efficiency, interference handling, and performance in noisy conditions. FBMC demonstrates better Adjacent Channel Power Ratio (ACPR), Signal-to-Interference-Plus-Noise Ratio (SINR), and Carrier-to-Interference-plus-Noise Ratio (CINR), making it a more reliable choice for applications requiring high reliability. Additionally, FBMC exhibits a lower Peak-to-Average Power Ratio (PAPR), further enhancing its robustness. Despite these advantages, FBMC comes with increased implementation complexity, primarily

due to the use of prototype filters and overlapping waveforms, which require more sophisticated processing techniques. Nonetheless, its performance benefits make it a strong candidate for advanced communication systems where reliability is critical.

## REFERENCES


1. Bellanger M. Specification and design of a prototype filter for filter bank based multicarrier transmission. In: IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP); 2012. p. 2417-2420.
2. Mattera D, Tanda M. Filter bank multicarrier with QAM modulation for future wireless systems. Signal Processing. 2016;120:594-606.
3. Nissel R, Rupp M. Bit error probability for pilot-symbol aided channel estimation in FBMC-OQAM. In: IEEE International Conference on Communications (ICC); 2017. p. 1-6.
4. Matz G, Schafhuber D, Grochenig K, Hartmann M, Hlawatsch F. Analysis, optimization, and implementation of low-interference wireless multicarrier systems. IEEE Trans Wireless Commun. 2017;6:1921-1931.
5. Na D, Choi K. Low PAPR FBMC. IEEE Trans Wireless Commun. 2018;17:182-193.
6. Basheer A, Habib A. Filter bank multi carrier based MIMO systems for 5G wireless communication. In: IWSLS; 2016 Jul; Islamabad, Pakistan.
7. Kansal P, Shankhwar AK. FBMC vs OFDM waveform contenders for 5G wireless communication system. Kanpur (India): Harcourt Butler Technical University; 2017.
8. Nissel R, Schwarz S, Rupp M. Filter bank multicarrier modulation schemes for future mobile communications. IEEE J Sel Areas Commun. 2017.
9. Abdulhussein AA, Abdullah HN. Comparative study of peak to average power ratio in OFDM and FBMC systems. Al-Nahrain University; 2021.
10. Yadav SP. Filter bank multicarrier modulation techniques for 5G and beyond wireless communication systems. Eur J Electr Eng Comput Sci. 2022.
11. Vakilian V, Wild T, Schaich F, ten Brink S, Frigon J. Universal-filtered multi-carrier technique for wireless systems beyond LTE. In: IEEE Globecom Workshops (GC Wkshps); 2013. p. 223-228. doi:10.1109/GLOCOMW.2013.6824990
12. Farhang-Boroujeny B. OFDM versus filter bank multicarrier. IEEE Signal Process Mag. 2011;28:92-112. doi:10.1109/MSP.2011.940267
13. Siohan P, Siclet C, Lacaille N. Analysis and design of OFDM/OQAM systems based on filterbank theory. IEEE Trans Signal Process. 2002;50:1170-1183. doi:10.1109/78.995073
14. Schaich F, Wild T, Chen Y. Waveform contenders for 5G—OFDM vs. FBMC vs. UFMC. In: 6th Int Symp Commun Control Signal Process (ISCCSP); 2014. p. 457-460. doi:10.1109/ISCCSP.2014.6877912
15. Oyman O, Sahin A, Guvenc I, Arslan H. Low-complexity channel estimation for FBMC-OQAM systems. IEEE Trans Signal Process. 2017;65:612-624. doi:10.1109/TSP.2016.262888